OUR HIGH-ENERGY PLANET

— A CLIMATE PRAGMATISM PROJECT —

By Mark Caine, Jason Lloyd, Max Luke, Lisa Margonelli, Todd Moss,
Ted Nordhaus, Roger Pielke Jr., Mikael Román, Joyashree Roy, Daniel Sarewitz,
Michael Shellenberger, Kartikeya Singh, and Alex Trembath

APRIL 2014

BREAKTHROUGH INSTITUTE

Consortium for Science, Policy & Outcomes
at Arizona State University

OUR HIGH-ENERGY PLANET

A CLIMATE PRAGMATISM PROJECT

THE CO-AUTHORS

Mark Caine
Breakthrough Institute

Jason Lloyd
Consortium for Science, Policy & Outcomes, Arizona State University

Max Luke
Breakthrough Institute

Lisa Margonelli
New America Foundation

Todd Moss
Center for Global Development

Ted Nordhaus
Breakthrough Institute

Roger Pielke, Jr.
Center for Science and Technology Policy Research, University of Colorado at Boulder

Mikael Román
Office of Science and Innovation, Embassy of Sweden

Joyashree Roy
Global Change Programme, Jadavpur University

Daniel Sarewitz
Consortium for Science, Policy & Outcomes, Arizona State University

Michael Shellenberger
Breakthrough Institute

Kartikeya Singh
Center for International Environment and Resource Policy, Fletcher School of Law & Diplomacy, Tufts University

Alex Trembath
Breakthrough Institute

APRIL 2014

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Today, over one billion people around the world—five hundred million of them in sub-Saharan Africa alone—lack access to electricity. Nearly three billion people cook over open fires fueled by wood, dung, coal, or charcoal. This energy poverty presents a significant hurdle to achieving development goals of health, prosperity, and a livable environment.

The relationship between access to modern energy services and quality of life is well established. Affordable and reliable grid electricity allows factory owners to increase output and hire more workers. Electricity allows hospitals to refrigerate lifesaving vaccines and power medical equipment. It liberates children and women from manual labor. Societies that are able to meet their energy needs become wealthier, more resilient, and better able to navigate social and environmental hazards like climate change and natural disasters.

Faced with a perceived conflict between expanding global energy access and rapidly reducing greenhouse emissions to prevent climate change, many environmental groups and donor institutions have come to rely on small-scale, decentralized, renewable energy technologies that cannot meet the energy demands of rapidly growing emerging economies and people struggling to escape extreme poverty. The UN's flagship energy access program, for example, claims that "basic human needs" can be met with enough electricity to power a fan, a couple of light bulbs, and a radio for five hours a day.

A reconsideration of what equitable energy access means for human development and the environment is needed. As this paper demonstrates, a massive expansion of energy systems, primarily carried out in the rapidly urbanizing global South, in combination with the rapid acceleration of clean energy innovation, is a more pragmatic, just, and morally acceptable framework for thinking about energy access. The time has come to embrace a high-energy planet.

This paper looks to history for guidance in achieving a high-energy world. Historically, energy modernization has been driven by a strong public commitment to expand modern energy services, ensure equitable energy access, and achieve broader economic development goals. Smart public policies will promote increasingly productive uses of energy, engage the private sector to ensure reliable and cost-effective services, support energy innovation activities, and proceed in concert with long-term development goals.

A commitment to a high-energy planet empowers growth and development using the broadest array of energy services, technologies, and policies that can meet the manifold needs of developing societies. The way we produce and use energy will become increasingly clean not by limiting its consumption, but by using expanded access to energy to unleash human ingenuity in support of innovating toward an equitable, low-carbon global energy system.

INTRODUCTION

Access to affordable and reliable energy is a prerequisite for human development. Modern energy undergirds every aspect of modern life, from education to healthcare, manufacturing to telecommunications, agriculture to transportation. Affluent countries have spent two centuries unlocking the potential of widespread energy access to improve the lives of their citizens and build dynamic, prosperous societies. Now, hundreds of millions of people in the developing world are using modern energy to escape poverty.[1] So overwhelming and undeniable is the importance of energy to quality of life that any agenda intent upon advancing human development and dignity must place universal and equitable access to modern energy services at its center.

A coherent strategy for human development begins with the assumption that energy equity is necessary for a just, prosperous, and environmentally sustainable society.

Rapidly emerging economies like Vietnam, Brazil, India, and South Africa have accelerated their development and improved their citizens' lives by focusing on economic growth, industrial productivity, and energy system modernization. As the poorest countries of the global South transition from agrarian to industrial societies, they are likely to follow a similar path, and they will require more energy as they do so. In seeking to assist these least-developed countries in their modernization, international organizations like the United Nations have highlighted the role of energy access in achieving development objectives. This is commendable. But as we will show, the energy access proposals outlined by these groups are constrained by a simultaneous focus on minimizing greenhouse gas (GHG) emissions in an attempt to deal with climate change. As a result, we argue, the levels of energy access envisioned by these initiatives are often inadequate for driving long-term socioeconomic development.

Rather than limiting energy access and consumption on the basis of their potential climate change impacts, a coherent strategy for human development begins with the assumption that energy equity is necessary for a just, prosperous, and environmentally sustainable society. By building out the worldwide energy system in support of human dignity and widely shared prosperity, we create fertile conditions for the emergence and scaling of new innovations that will generate progressively lower-carbon developmental pathways. As this paper will explain, it is precisely the massive expansion—rather than contraction—of energy systems, carried out primarily in the inexorably urbanizing South, that provides the context and opportunity for a robust, coherent, and ethical response to the global challenges we face.

Our high-energy framework is prescriptive only in its commitment to equity. The appropriateness of energy technologies is determined by their ability to meet the current and—in order to avoid locking in energy poverty through low levels of access—the *future* energy needs of individuals and societies. Our approach combines a commitment to pragmatism with an insistence that all humans deserve access to sufficient energy services to afford them the quality of life currently enjoyed by people in economically developed regions of the world. A high-energy planet with universal access to affordable, cleaner, and plentiful energy, we argue, is the most practical way to secure this socioeconomic development while ensuring environmental protection.

Sabarmati Thermal Power Station, which powers the Indian cities of Ahmedabad and Gandhinigar (Photo credit: Koshy Koshy)

ENERGY ACCESS TRENDS

ENERGY, PRODUCTIVITY, AND HUMAN DEVELOPMENT

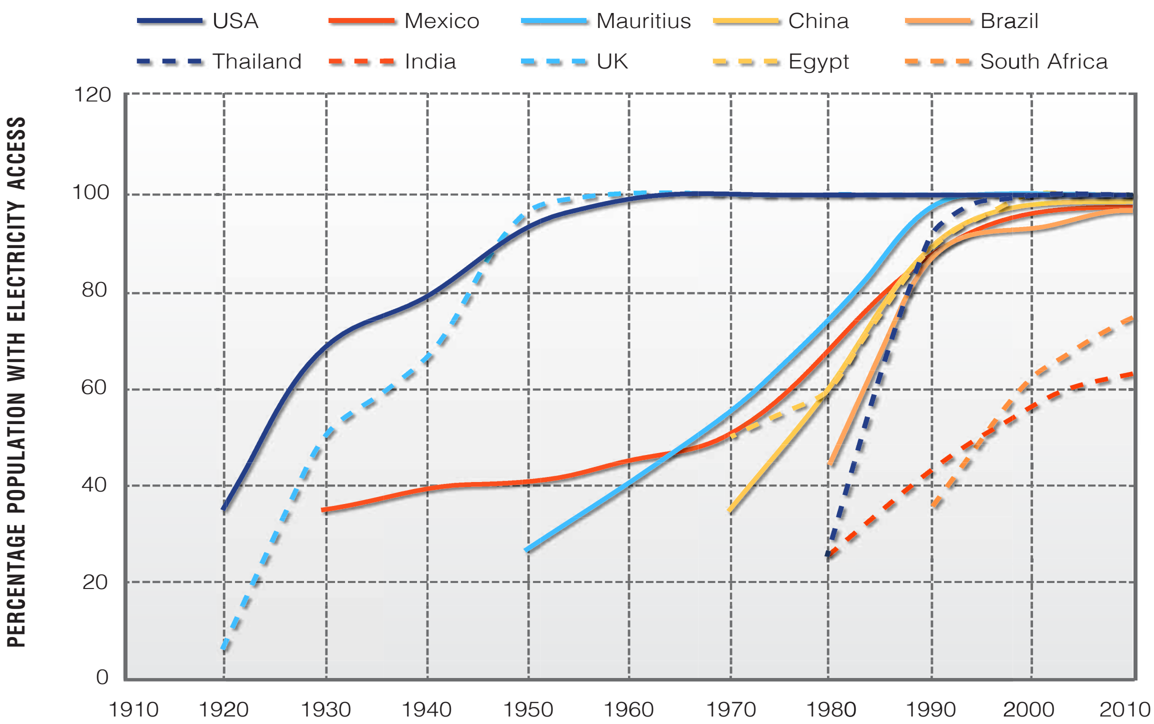
Energy access, economic productivity, and social well-being have co-evolved over the past two centuries as central features of a broader societal advancement process characterized by sustained growth in the capacity to cultivate knowledge and skills that lead to further innovation, prosperity, and resilience. Central to this co-evolution has been the ability of every citizen and business to take advantage of affordable and reliable energy in the form of electricity and other modern fuels.

The relationship between access to modern energy services and quality of life is well established. Two hundred years ago, as the economies of industrializing countries prospered and their populations began transitioning from traditional biomass fuels to the precursors of the energy sources in use today, living standards improved dramatically. The same is true today in the developing world. As poor people gain access to electricity and cleaner fuels, they typically enjoy longer, healthier, and more prosperous lives.

Universal energy access also powers modern, growing economies. The transformation of natural energy assets into usable energy services allows not just for household lighting and electricity, but also modern infrastructures and industrial practices that have positive social impacts. Affordable energy is used to power tractors, create fertilizers, and power irrigation pumps, all of which improve agricultural yields and raise income. Cheap and reliable grid electricity allows factory owners to increase output and hire more workers. Electricity allows hospitals to refrigerate lifesaving vaccines and power medical equipment. It liberates children and women from manual labor and provides light, heat, and ventilation for the schools that educate the workforce.

Like freedom from violence, hunger, and the diseases of poverty, access to sufficient levels of energy must be understood as a cornerstone of human development.

While there is no single or linear path to a modern energy system, there is a pattern common to many societies. As countries like the United States and Great Britain shifted from agrarian to industrial to postindustrial societies, they developed more efficient, flexible, and convenient energy sources to power increasingly complex economic activities. From an almost total reliance on biomass fuels like wood and charcoal in the early 1800s, advanced economies now depend on reliable, grid-based access to a diverse mix of energy resources, including coal, oil, natural gas, hydropower, nuclear fission, and renewables like wind and solar. Technical innovation, economies of scale, government investments, and competitive markets for energy services improved the performance of these energy systems, lowered their costs, enhanced the services they provide, and spurred the generation of new services that benefitted lives and livelihoods.[2]



In this sense, we understand the development that energy supports to mean much more than just economic growth. Rather, development involves building knowledge and skills that allow a society to innovate, solve problems, enhance productivity, and improve processes, capabilities, and technologies.[3] Historically, such increases in society-wide capacity have allowed countries and their citizens to reduce the amount of carbon they burn per unit of energy produced—that is, to decarbonize their energy systems—and to advance along trajectories of their choosing, as people with access to energy and the opportunities it enables acquire freedom of choice about how they live and what livelihoods they pursue. Societies that are able to meet their energy needs become wealthier, more resilient, and better able to navigate social and environmental hazards like climate change. Therefore, like freedom from violence, hunger, and the diseases of poverty, access to sufficient levels of energy must be understood as a cornerstone of human development.

While the world has made considerable progress in expanding energy provision, billions of people still have far too little access to energy. Today, the poorest three-quarters of the world's population use just one-tenth of the world's energy. Over one billion people around the world—five hundred million of them in sub-Saharan Africa alone—lack access to electricity. Nearly three billion people cook over open fires fueled by wood, dung, coal, or charcoal.[4] The health consequences of these energy use patterns are severe: every year, indoor air pollution causes two million premature deaths, one million cases of chronic obstructive pulmonary disease, and half of all of pneumonia deaths among children under the age of five.[5]

AN URBAN PLANET: PEOPLE TO THE POWER

Urbanization is shaping the context for expanded energy access and energy innovation. Demographic trends in the developing world demonstrate an inexorable transition from rural, pastoral societies toward industrial, urban societies.[6] This transition makes countries wealthier, more productive, and more innovative, but sustaining these advances requires large quantities of energy. High population densities require large-scale, centralized energy sources such as hydropower, coal with carbon-capture and sequestration (CCS), advanced nuclear, and natural gas, along with the efficient networked configurations of gas pipelines and electricity grids.[7]

Historically, most rural dwellers have gained access to modern energy services by moving to cities.[8] To be sure, rural electrification efforts have played an important role in ensuring access in industrial countries. But such success in electrification has been facilitated at least in part by the fact that the rural population in need of electricity was shrinking amidst a broader context of economic growth driven by expanding urban industrial centers. There remain, of course, billions of people who live in rural communities, and there will be for many decades to come. The solutions to energy poverty in remote, rural villages will, of necessity, look quite different from solutions in urban areas. But most of the increase in global energy access through the next century is likely to be the result of urbanization combined with better urban electrification efforts.

Urbanization contributes to universal electrification in three distinct ways. It shifts populations into denser living configurations that are less costly to electrify, which is why, for instance, 60 percent of urban citizens in sub-Saharan Africa have electricity access whereas only

14 percent of rural residents do.[9] It reduces the size of rural populations that must be served through expensive grid extensions. And it results in more affluent societies that are better able to provide a critical mass of urban consumers who can support a financially sustainable energy system.[10] These factors underlie the historical pattern of universal electrification in rich countries and the provision of energy services to their rural or remote populations.

Nonetheless, the archetypal image evoked by efforts to address energy poverty is the desperately poor rural village, not the sprawling informal urban slum. And while the critical needs of rural communities should not be ignored, global energy and climate policies, in order to succeed, will need to focus much more heavily on the needs of rapidly growing urban populations in developing economies. National electrification plans that envision generating capacity and infrastructure to power growing cities and densely population peri-urban regions should be central priorities for development organizations and multilateral institutions like the UN.

ENERGY ACCESS AS A PUBLIC GOOD

The kind of large-scale, long-term planning required for equitable energy access points to an important facet of the policy framework for achieving a high-energy planet: the need for effective and responsive public governance, in cooperation with the private sector, which takes into account factors like the wider economy, environmental impacts, and public safety. The provision of reliable energy services is in many ways unique—enormously complex, operating over decades, risky for investors, and with weak market signals—and the private sector alone lacks the capacity and incentives to make energy systems significantly cleaner or more equitable, particularly for very poor and marginalized energy consumers.

> Guaranteeing access to modern energy services is a way of utilizing collective national resources to create a public good from which all people benefit.

As a result, energy modernization has been driven, almost everywhere, by a strong public commitment to expanding access to modern energy services in pursuit of both equitable energy access and broader economic development goals. Public utility companies or highly regulated monopolies sought secure energy supplies and low-risk efficiencies to ensure affordable prices, guaranteed profits, and high rates of economic growth.[11] States partly subsidized the creation and extension of electric grids, typically through loan-interest financing, early losses recovered through increased consumption later, and strategic tariff structuring. Individual and commercial consumers then came to expect the most cost-effective and reliable energy sources to power their homes, vehicles, and businesses.

A powered irrigation system in Mpongwe, Zambia

Guaranteeing access to modern energy services is a way of utilizing collective national resources to create a public good from which all people benefit. Effective states have long recognized this, which is why the energy infrastructure of all industrially developed nations—and those of late-industrializing countries like China, Chile, Mexico, Thailand, Tunisia, and others—has been dominated by either public or heavily regulated institutions.[12] Just as no country leaves the construction and maintenance of its transportation networks or public health systems to the complete mercy of the market, public policy and financing for building and modernizing a country's energy system—one of the most basic responsibilities of a functioning state—is necessary. Only public sector involvement can devote resources on the requisite scale, ensure that abundant and affordable energy services reach all citizens, and create the stable economic and political conditions necessary to expand private investment.

Countries as varied as Brazil, Indonesia, and Vietnam have made substantial progress toward universal energy access. Through public financing and proactive legislative support, they have created conditions for private investment in the energy system, fostered competition and efficiency in end-use technologies, and mitigated market failures like underinvestment in innovation, infrastructure, and rural electrification. Such public leadership in the energy sector—often demanded by industrial sectors that need reliable energy in order to be competitive—typically instigates a virtuous cycle of increased energy access, rising incomes and political agency, and more responsive policies that provide citizens with plentiful, reliable, and cleaner energy services. Indeed, countries that have successfully electrified have consistently relied upon encouraging productive use of electricity like water pumps for agriculture, or refrigeration for food and medicine distributors.[13]

DECARBONIZATION

Creating a high-energy planet and building out the infrastructure necessary for universal and equitable access to energy involves immense changes in technical, social, economic, and environmental systems. These changes often have multiple benefits. Transitioning from dung and wood to coal, natural gas, nuclear, and other advanced energy sources alleviates many problems caused by a lack of energy access or the use of low-grade energy sources, including deforestation, soil erosion, black carbon emissions, and respiratory ailments that lead to premature death.

Modern energy is crucial not just for human development, but also for environmental quality, as it allows developing nations to move away from traditional, polluting energy sources and toward cleaner fuels. Modern energy systems use relatively less carbon per unit of energy produced than pre-industrial systems. Charcoal, a biomass fuel still used in many parts of the developing world, is almost pure carbon. Over time, our consumption of hydrocarbon fuels has shifted towards sources of energy with ever-higher hydrogen-to-carbon ratios. Natural gas has half the carbon content of coal, and nuclear power and renewable sources emit no carbon dioxide in energy production.

This historical path of decarbonization has not prevented a continual rise of global carbon emissions because more efficient, affordable energy services have precipitated dramatic increases in energy consumption. Much of the energy that underpins worldwide economic activity comes from burning fossil fuels that emit greenhouse gases and other pollutants, making the global energy system the largest contributor to global climate change. This fact has created the appearance of a conflict between the energy needs of developing countries and the need to address climate change. The logic of this conflict suggests that because energy is implicated in the climate change problem, energy production and consumption should be minimized and emissions reduced whenever and wherever possible.

The risks presented by climate change should not and will not be managed through limiting access to energy by the populations who need it most.

This idea that energy use must be constrained, or restricted to specific zero-carbon technologies, informs the dominant framework within which energy and human development are understood by many environmental organizations, donor governments, and multilateral development agencies, typically based in the United States and Europe.[14] Often manifested in subtle and implicit ways, this framing is especially evident in the low quantitative thresholds of international energy access initiatives;[15] in "climate stabilization scenarios" and energy consumption projections that assume billions of people will remain without access to modern energy for the foreseeable future;[16] and in international climate negotiations that focus on low-emission hardware transfers rather than social and economic development along technological pathways that do not trade near-term energy access for long-term climate goals.[17]

The energy access report from the UN's Advisory Group on Energy and Climate Change, for example, notes that "energy facilitates social and economic development," while arguing that the world's least-developed countries must "expand access to modern energy services … in a way that is economically viable, sustainable, affordable and efficient, and *that releases the least amount of GHGs.*"[18] In other words, the UN supports human development through expanded energy access, so long as that energy does not come from the cheap fossil fuels that wealthy, developed countries spent the past two centuries burning, and that in many developing world contexts remain the cheapest, most reliable, and most versatile energy options. Energy access initiatives (such as those described below) are structured within a dominant climate narrative that denigrates—often in explicitly moral terms[19]—many forms of energy production and consumption. In practical terms, such approaches seek to minimize, or even forbid, the use of the very energy technologies that enabled the prosperity of developed countries, and that are now spurring the rapid growth of many economies in the developing world.

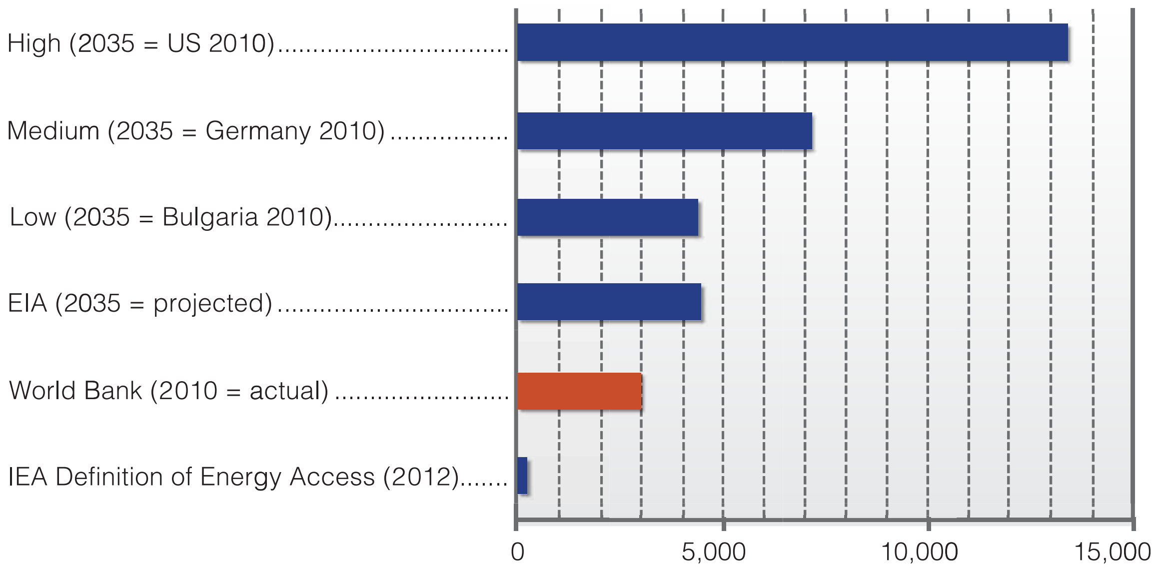
The unacknowledged problem is that aside from nuclear and hydroelectric power, which most people in the environmental and development communities do not strongly advocate, there are not yet reliable, scalable, clean, base-load energy sources available to take the place of incumbent fossil fuels. Building out efficient grid infrastructure and modernizing the energy sector—including shifting from coal to coal and natural gas with carbon capture, hydroelectric, and advanced nuclear power—are key processes in shifting to a low-carbon global energy system. Accelerating such a transition should be the priority of the climate and development communities, since the risks presented by climate change should not and will not be managed through limiting access to energy by the populations who need it most in order to thrive, innovate, and prosper.

INADEQUATE ENERGY ACCESS GOALS

Fortunately, the last few years have seen a growing international commitment to universal energy access. United Nations Secretary General Ban Ki-Moon has made universal electrification one of his highest priorities, and the UN declared 2012 the Year of Sustainable Energy for All (SE4All). In June 2013, President Obama announced a $7 billion effort to "Power Africa," aimed at extending electricity to 20 million households. Currently the US Congress is considering legislation, "The Electrify Africa Act" (H.R. 2548), to extend electricity to 50 million people. These efforts involve the Export-Import Bank, the Overseas Private Investment Corporation (OPIC), the Millennium Challenge Corporation, the U.S. Trade and Development Agency, and the U.S. Agency for International Development. Power Africa also includes $9 billion in commitments from private companies such as General Electric.

AN AMBITION GAP IN GLOBAL ENERGY ACCESS?

Global Per Capita Electricity Consumption (kWh/year)



These new initiatives have prioritized improved energy access as a means of achieving larger development objectives like economic growth, public health, and education. But, bounded by the conventional GHG-reduction framework outlined above, even when universal energy access is a declared objective, the thresholds are typically unacceptably low and far from equitable. The SE4All initiative, for example, claims that "basic human needs" can be met with enough electricity to power a fan, a couple of light bulbs, and a radio for five hours a day,[20] a baseline that someone from a rich country would not recognize as access at all. The average European consumes SE4All's yearly energy access threshold in less than a month,[21] and a typical American burns through that much electricity in a little over a week.[22] More importantly, such a baseline does not capture electricity used outside the home to power hospitals, schools, government facilities, commercial buildings, factories, and all the other places and activities that require electricity.[23]

The same is true for other major energy access initiatives. The International Energy Agency (IEA) defines "energy access" as 500 kilowatt-hours (kWh) per year, or 100 kWh per person,[24] which is about 0.5 percent of the levels consumed by the average American or Swede, or 1.7 percent of the average Bulgarian. The World Bank's highest tier for energy access is less than 10 percent what the average Bulgarian uses. While acknowledging that these are initial targets and that efforts must be realistic in their goals to be seen as credible, it is nonsensical to argue, as these goals implicitly do, that a household has achieved equitable access to modern energy when consuming 50 to 100 kWh per person annually—less than the average American's cable television box.[25]

The problem is not simply that these modest thresholds for energy access are low in comparison with high-income countries; after all, the immediate energy needs of poor communities in developing nations are much different from the energy demands of citizens in Canada or Germany. What *is* problematic is that these minimal targets can be met with energy technologies that have little capacity for scaling up and meeting the expanding needs of economically productive, non-household activities like manufacturing, transportation, or commercial agriculture.

Existing energy access initiatives can fully succeed on their own terms without any meaningful or sustained development on the part of energy-poor communities.

Without a viable mechanism for individuals, communities, or private enterprises to move up the energy ladder for improved quality of life and greater productivity, achieving negligible access thresholds with technologies like rooftop solar panels or cleaner cookstoves—rather than, for example, reliable grid connections—leaves other human development goals far out of reach. And because access initiatives are not typically part of long-term electrification strategies at the national or regional level, they do not support either effective development planning or the delivery of high-quality energy services to critical sectors of the economy.[26]

Illegal grid connections in Rio de Janiero's Rocinha favela illustrate the demand for adequate and affordable energy (Photo credit: Alicia Nijdam)

Put simply, initiatives like SE4All can fully succeed on their own terms without any meaningful or sustained development on the part of energy-poor communities. Whatever the short-term benefit, a narrow focus on household energy and the advocacy of small-scale energy sources like solar home systems can, in fact, make it *more* difficult to meet the soaring increase in energy demand associated with moving out of extreme poverty.[27] Not only do such low thresholds drastically underestimate the magnitude of the energy access challenge, they also further entrench global inequities, distract financial and political capital away from more productive investments, and prevent people and nations from pursuing development paths that offer greater hope for reconciling their socioeconomic and environmental aspirations over the long term.

As a result, contemporary advocacy of sustainable energy expansion too often offers wildly inappropriate solutions, sometimes lifted wholesale from developed-world contexts that make no sense for energy-poor nations. For instance, despite being the world's sixth largest oil exporter, with vast reserves of natural gas, coal, and renewable energy, Nigeria has some of the lowest rates of energy access in the world.[28] The United Nations Development Programme's remarkable response to this situation is a project to "improve the energy efficiency of a series of end-use equipment ... in residential and public buildings in Nigeria through the introduction of appropriate energy efficiency policies and measures." Much of this $10 million project involves distributing compact fluorescent light bulbs.[29] The point is not that improving efficiency is ineffective in reducing carbon emissions, or that energy systems should not be made as efficient as possible in order to stimulate energy use for productive ends. It is that efficiency initiatives like these are entirely inadequate for development needs in energy-destitute countries like Nigeria.

On-demand grid electricity capable of powering commercial agriculture, modern factories, and megacities in the developing world will likely drive energy and development strategies for the foreseeable future.

The Nigeria case typifies why many present-day international sustainable energy initiatives, constrained by a framework that prioritizes emissions reductions even for the poorest, least-emitting countries, are ill suited to the development priorities of the emerging economies. If universal energy access, properly understood as a broad development imperative, is to build on past lessons from the rich world and resonate with the ambitions of late-industrializing countries, it will in most cases entail the provision of reliable grid electricity.[30]

As with all large-scale technological transitions, this will be an evolutionary process, one that may begin with technologies like regional micro-grids. But on-demand grid electricity capable of powering commercial agriculture, modern factories, and megacities in the developing world will likely drive energy and development strategies for the foreseeable future. International energy access and climate initiatives that fail to align themselves with these priorities are largely irrelevant to the pursuit of decent living standards among those who currently lack access to modern energy services.

ENERGY SECTOR BUILD-OUT

Energy systems have grown as countries have sought to meet their economic and social aspirations. Between 1990 and 2010, emerging lower-middle-income nations increased the percentage of their populations with access to electricity by 19 percent, to more than three-quarters of their populations. Regionally, the countries of southern Asia improved electricity access by 23 percent over the same time period, and North Africa went from 85 percent electricity access to almost 100 percent. Individual countries have seen even more impressive energy sector expansion: in Indonesia, for example, 94 percent of citizens now have electricity access, up from 67 percent in 1990.[31]

This expansion generates performance efficiencies and cost reductions that are advanced incrementally through technological demonstration, deployment, and improvement through day-to-day operations. These improvements within a relatively stable system of institutions, skills, markets, political interests, and cultural forces can lead to what in hindsight are seen as breakthrough innovations toward new and cleaner energy technologies.[32] Concerted public and private efforts to develop and diffuse those innovations have succeeded in accelerating the rate at which energy systems shift to lower-carbon, more affordable technologies. Innovations in unconventional natural gas production over the past decade, for example, have lowered natural gas prices by 65 percent in the past five years[33] and led to historic reductions in U.S. carbon emissions.[34] In the 1970s and 80s, improved operating practices across the U.S. nuclear reactor fleet led to increases in capacity factors (the fraction of the actual-to-available power being generated) from an average of about 50 percent to 90 percent. This was a consequence of improved operating practices that came from use and experience, not from new technologies.

In other words, much of the opportunity for innovation in energy technologies over the next century will occur where and when new technology is needed and being actively deployed—that is, in emerging economies. Rich countries that have already met most of their energy needs will provide fewer opportunities than the late-industrializing countries for large-scale diffusion and improvement of new energy technologies, especially those providing large base-load generation and distribution. However, improved coordination between rich countries, with established innovation capabilities, and late-industrializing nations, which are rapidly building out their energy systems, on improving energy technologies will both accelerate innovation toward low-carbon energy systems and help to universalize equitable access to cleaner energy. Efforts to alleviate energy poverty therefore create highly favorable conditions for the development and diffusion of affordable low-carbon energy technologies.

Training in China for the operation of the Westinghouse AP1000 nuclear reactor (Photo credit: NRC)

China provides the most obvious example. It has demonstrated significantly lower costs for capturing carbon emissions from power plants than any other country.[35] It is a world leader in cost-effective hydroelectric power.[36] China has at least 28 nuclear reactors under construction, compared to five in the United States, and it is taking the lead in pushing forward advanced nuclear technologies like gas-cooled pebble-bed reactors and molten salt thorium-fed reactors. Innovations that improve performance and cost through technology deployment, though not guaranteed,[37] are much more likely to accrue to China and the companies that work there than to countries where energy demand is flat and energy systems are technologically, politically, and economically entrenched. And though the scale and intensity of effort in China is exceptional, other industrializing countries offer comparable opportunities. With sustained and coordinated financial, institutional, and technical support, similar systemic development in support of improved energy access can happen in the least-developed countries, providing the foundation for a truly global energy innovation system.

The variety of energy consumers and the services they require highlight how crucial it is for energy access and innovation to be context-appropriate. Energy needs are dependent on climate, geography, culture, economics, and a range of other factors. Highly urban and industrialized China, with its huge coal reserves, may profitably invest in carbon capture and storage technologies for its base-load coal power plants; the dispersed rural populations of Ethiopia may depend on extending grid infrastructure in order to exploit the country's abundant hydropower resources. And for remote communities around the world, distributed solar or wind generation and micro-grids may prove critical in providing access to energy. The sheer diversity of contexts in which energy expansion will take place demands technological pluralism, meaning a commitment to moving innovation forward on nuclear,[38] fossil fuels, hydropower, solar, wind, transportation, infrastructure, and all other energy sources and services that can be made more affordable, cleaner, and socially acceptable.

INNOVATION FOR CLIMATE MITIGATION

Energy modernization provides the foundation for future innovations and technology options that will lead to an increasingly clean global energy system. Furthermore, as societies increase their reliance on electricity and fuels with greater energy content and less carbon, delivered through efficient grid systems, there are substantial positive impacts on human wellbeing, economic productivity, and local environment—the pillars of sustainable development. Any morally acceptable and politically coherent path to reconcile equitable energy access with successful climate action must be pursued not by minimizing energy consumption, but with the catalytic combination of equitable energy access and more energy innovation.

Because it generates greater human and capital resources with which to innovate, modern energy-supported development advances societies and their energy systems along trajectories distinct from, and ideally lower-carbon than, those traversed by the rich world.[39] This framework for development also enriches the potential for international, collaborative innovation efforts, since the contexts for energy services, low-carbon innovation, and equitable access vary tremendously worldwide. The legitimate starting place for such collaboration is an explicit commitment to the kind of energy equity that enables an escape from subsistence living and fosters the capacity to prosper, adapt, and innovate.

Because it generates greater resources with which to innovate, modern energy-supported development advances societies and their energy systems along distinct trajectories.

The certain and irreversible global growth in energy consumption in turn provides the foundation for accelerating the technological, financial, and institutional innovations necessary to speed the transition to a low-carbon global energy system. Most energy consumption growth will come from late-industrializing countries as they fulfill their development ambitions, but ensuring that the least-developed countries, and poor and marginalized communities worldwide, benefit equitably from this expansion will remain a challenge. Yet with planning and imagination, escalating consumption is precisely—and counterintuitively—the process through which energy systems will develop along just and progressively lower-carbon pathways. By taking advantage of two global trends—the shift to an urbanized planet and the extraordinary growth of the energy sector in the developing world—we discover a pragmatic, plausible, and inclusive route to universalizing energy access and innovating toward low- or no-carbon energy futures.

CONCLUSION

Moving toward a high-energy planet is a moral imperative. By building on trends like urbanization and energy-sector expansion in developing countries, we discover greater opportunities for achieving human development goals. Pursuing this agenda will not be easy or inexpensive, as there is no simple answer to difficult decisions about how to invest limited human, economic, and technical resources. But a high-energy planet is inherently enfranchising, empowering, and optimistic, and it works with rather than against the momentum of ongoing changes in an industrializing and urbanizing world. Our vision of a high-energy world can thus appeal to broad and diverse constituencies in ways that continue to escape the standard low-energy approach to climate policy.

The Vidigal favela in Rio de Janeiro, Brazil (Photo credit: Roney)

By recasting engagement with the developing world within a high-energy framework, we create a foundation from which socioeconomic development and cleaner energy trajectories can be pursued. Groups and governments seeking to productively engage with the least-developed countries must address sector-wide energy problems through technical assistance, subsidy support, financing, and institutional capacity building, in order to help these countries take full advantage of their energy resources for the benefit of their citizens.[40] In rapidly growing economies like China, Brazil, and India, a focus on partnering with innovative energy institutions will be key to creating and massively diffusing the innovations that will decarbonize the global energy system and make energy available and affordable for all consumers. Such effective collaboration will be the subject of our next report, on innovation for a high-energy planet.

It will take tremendous effort, capital, and political will to ensure that the ongoing expansion of the energy sector in developing nations provides all people with access to energy they can afford as soon as possible, and to support efforts that will make that energy progressively cleaner. But a high-energy framework aligns itself with the trends that are shaping the planet's future, improving the outcomes of these forces rather than futilely trying to stop or reverse them. A framework for expanding energy access is no framework at all if it neglects the rapidly urbanizing global population, the benefits of modern electricity grids and energy delivery systems, and the moral imperative of energy abundance and equity. Our vision of a high-energy planet is one in which human equity and well-being are top priorities, in which energy access is critically linked to governance and broader socioeconomic development, and in which the consumption and technology preferences of the rich world do not limit the ambitions and investments of developing countries.

ENDNOTES

1 United Nations Development Programme, *Human Development Report 2013, The Rise of the South: Human Progress in a Diverse World* (New York, NY: UNDP, 2013).

2 Vaclav Smil, *Energy Transitions: History, Requirements, Prospects* (Santa Barbara, CA: Praeger, 2010).

3 Rob Byrne, Adrian Smith, Jim Watson, and David Ockwell, *Energy Pathways in Low-Carbon Development: From Technology Transfer to Socio-Technical Transformation* (Brighton, UK: STEPS Centre, STEPS Working Paper 46, 2011).

4 International Energy Agency, "Measuring Progress Towards Energy for All," Ch. 18 in *World Energy Outlook 2012* (Paris, France: OECD/IEA, 2012), available at: http://www.worldenergyoutlook.org/media/weowebsite/energydevelopment/2012updates/Measuringprogresstowardsenergyforall_WEO2012.pdf

5 Kirk R. Smith, Sumi Mehta, and Mirjam Maeusezahl-Feuz, "Indoor air pollution from household use of solid fuel," in *Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors*, Vol. 2, Majid Ezzati, Alan D. Lopez, Anthony Rodgers, and Christopher J. L. Murray, eds. (Geneva: World Health Organization, 2004).

6 United Nations Human Settlements Programme, *Planning Sustainable Cities: Global Report on Human Settlements 2009* (London, UK and Sterling, VA: UN Habitat and Earthscan, 2009).

7 See Jesse H. Ausubel, "Decarbonization: The Next 100 Years" (Austin, TX: 50th Anniversary Symposium of the Geology Foundation, Jackson School of Geosciences, University of Texas, Apr. 25, 2003).

8 Douglas Barnes (ed.), *The Challenge of Rural Electrification: Strategies for Developing Countries* (Washington, DC: Resources for the Future, 2007).

9 Worldwide, urban and rural residents have electricity access at rates of 93.7% and 68%, respectively. International Energy Agency, "Access to Electricity," (2009), available at: http://www.worldenergyoutlook.org/resources/energydevelopment/accesstoelectricity/

10 World Bank, *Addressing the Electricity Access Gap* (Washington, DC: World Bank Group, June 2010).

11 Smil, *Energy Transitions*.

12 Liberalized (or deregulated) electricity markets are a relatively new phenomenon in wealthy countries, and came about only *after* near universal access had been achieved.

13 Barnes, *The Challenge of Rural Electrification*.

14 For example, the Brundtland Report, the foundational document of sustainable development, concludes: "It is clear that a low energy path is the best way towards a sustainable future." World Commission on Environment and Development, *Our Common Future* (Oxford, UK: Oxford University Press, 1987).

15 See, for example: World Bank, *Global Tracking Framework* (Washington, DC: World Bank Sustainability for All Program, 2013).

16 Roger Pielke, Jr., "How Much Energy Does the World Need? Clarifying the 21st Century Energy and Climate Challenges," The Breakthrough Institute (26 Feb. 2013), available at: http://thebreakthrough.org/index.php/voices/roger-pielke-jr/how-much-energy-does-the-world-need/

17 Byrne, et al., *Energy Pathways in Low-Carbon Development*.

18 Advisory Group on Energy and Climate Change (AGECC), *Energy for a Sustainable Future: Summary Report and Recommendations* (New York, NY: United Nations, April 2010), p. 8 (emphasis added).

19 See, for example: Friends of the Earth International, *Good Energy Bad Energy: Transforming Our Energy System for People and the Planet* (Amsterdam, Netherlands: Friends of the Earth International, 2013); and James Hansen, open letter to Michelle and Barack Obama (Dec. 29, 2008), available at: http://www.columbia.edu/~jeh1/mailings/2008/20081229_DearMichelleAndBarack.pdf

20 AGECC, *Energy for a Sustainable Future*.

21 Average per capita electricity consumption in Europe is approximately 1,500 kWh. See: World Energy Council, *Energy Efficiency Policies Around the World: Review and Evaluation* (London, UK: World Energy Council, 2008), p. 30.

22 Eight point three days, to be exact. Average surveyed household electricity consumption is 11,280 kWh per year and average household size is 2.6 people, meaning per capita domestic consumption in the U.S. is 4,338 kWh per year. See: U.S. Energy Information Agency, "How much electricity does an American home use?" (2013), available at: http://www.eia.gov/tools/faqs/faq.cfm?id=97&t=3

23 Per capita electricity usage in the United States rises to nearly 14,000 kWh per year when total electricity consumption is incorporated. See World Bank, *World Development Indicators: Power and Communications* (2013), available at: http://wdi.worldbank.org/table/5.11

24 International Energy Agency, *World Energy Outlook 2010* (Paris, France: OECD/IEA, 2010), p. 249.

25 See: Energy Information Agency, "End-Use Consumption of Electricity 2001," available at: http://www.eia.gov/emeu/recs/recs2001/enduse2001/enduse2001.html

26 Morgan Bazilian and Roger Pielke, Jr., "Making Energy Access Meaningful," *Issues in Science and Technology* (Summer 2013), pp. 74-78.

27 A World Bank report notes "an important advantage of the grid connection over the [solar home system], namely that increased electricity consumption by a grid consumer reduces its levelized cost per kWh significantly, whereas an increase in demand by a household relying on a SHS would require purchasing a second SHS, which would not reduce the levelized cost at all, or a larger unit, which would reduce the cost only slightly." See World Bank, *Addressing the Electricity Access Gap* (Washington, DC: World Bank Group, June 2010), p. 36.

28 Morgan Bazilian, Ambuj Sagar, Reid Detchon, and Kandeh Yumkella, "More heat and light," *Energy Policy*, Vol. 38 (2010), pp. 5409-5412.

29 United Nations Development Programme, "Promoting Energy Efficiency in Residential and Public Sector in Nigeria," UNDP Project Document (2011), available at: http://www.ng.undp.org/energy/EE-project-document.pdf

30 Douglas Barnes and Gerald Foley, *Rural Electrification in the Developing World: A Summary of Lessons from Successful Programs* (Washington, DC: UNDP/ World Bank Energy Sector Management Assistance Programme, Dec. 2004), p. 6 (emphasis added).

31 World Bank, "Energy Access." *Global Tracking Framework*, (Washington, DC: World Bank Group, 2013), pp. 262-270.

32 Frank W. Geels, "Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study," *Research Policy*, Vol. 31 (2002), pp. 1257-1274.

33 Nasdaq, "U.S. National Average Gas Price," available at: http://www.nasdaq.com/markets/natural-gas.aspx?timeframe=10y

34 Alex Trembath, Michael Shellenberger, Ted Nordhaus, and Max Luke, "Coal Killer: How Natural Gas is Fueling a Clean Energy Revolution," The Breakthrough Institute (June 2013).

35 Robert C. Marley, "U.S.-China Clean Energy Research Center," presentation to the MIT Club of Washington (4 Feb. 2013), available at: http://www.us-china-cerc.org/pdfs/Marlay_US-China_CERC_MIT_4-FEB-2013_v10.pdf

36 International Renewable Energy Agency, *Hydropower: Renewable Energy Technologies: Cost Analysis Series*, Vol. 1: Power Sector, Issue 3/5 (Bonn, Germany: IRENA Working Paper, June 2012).

37 Arnulf Grübler, "The costs of the French nuclear scale-up: A case of negative learning by doing," *Energy Policy*, Vol. 38 (2010): pp. 5174-5188.

38 Joyashree Roy and Shyamasree Dasgupta, "The Economics of Nuclear Energy: Revisiting Resurrection," *Artha Beekshan*, Vol. 19, No. 1 (June 2010).

39 Byrne, et al., *Energy Pathways in Low-Carbon Development*.

40 World Bank, *Addressing the Electricity Access Gap*.

IMPLMENTING CLIMATE PRAGMATISM

A joint project of the Consortium for Science, Policy & Outcomes at Arizona State University and The Breakthrough Institute, made possible with the generous support of the Nathan Cummings Foundation.

DISCLAIMER

The opinions expressed in this document are those of the authors, and the views expressed here do not necessarily represent those of the institutions with which the authors are affiliated.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to Armond Cohen, Sharlissa Moore, and Aneri Patel for their insights and contributions to the revision of this report. We also thank Jenna Mukuno (Breakthrough Institute) for her editing assistance and Dita Borofsky for graphic design and layout of the report. Finally, we express our sincere appreciation for the generous support of the Nathan Cummings Foundation, without which this report would not have been possible.

OUR HIGH-ENERGY

PLANET

— A CLIMATE PRAGMATISM PROJECT —

APRIL 2014

BREAKTHROUGH INSTITUTE

Consortium for Science, Policy & Outcomes
at Arizona State University